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㉛ Applicant: **TEKTRONIX, INC.**
Tektronix Industrial Park D/S Y3-121 4900 S.W. Griffith Driva P.O. Box 500
Beavarton Oregon 97077(US)

⑫ Inventor: **Grallman, H. Erwin**
6917 S.W. 179th Avanua
Beavarton Oregon 97007(US)

⑫ Inventor: **Raagan, John J.**
1855 S.W. Clifford
Beavarton Oregon 97005(US)

⑫ Inventor: **Roland, Leonard A.**
5289 N. Harvard
Portland Oregon 97203(US)

⑫ Inventor: **Laakso, Carl W.**
4080 N.w. 190th
Portland Oragon 97229(US)

㉔ Reprasentative: **Wombwall, Francis et al,**
Potts, Kerr & Co. 15, Hamilton Square
**Birkanhaad Merseysida L41 6BR(GB)**

㊿ Coplanar microstrap wavegulda.

㊐ An electrical connection between two semiconductor devicas employs a coplanar microstrap waveguide comprising a plurality of thin straps (28, 30, 32) of conductive metal embedded in a polyimide substrate (26) and dimensioned to exhibit the properties of a coplanar waveguide. The waveguide structure provides the proper impedance matching betwaen the two devices and enables them to handle signals having frequencies in the gigahertz range.

FIG. I
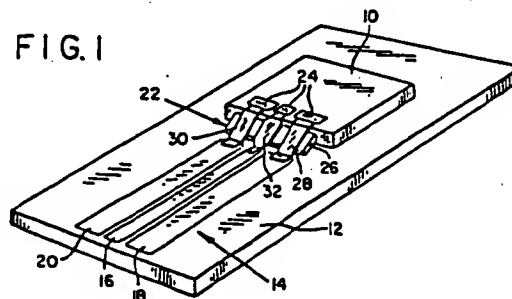
COPLANAR MICROSTRAP WAVEGUIDE

BACKGROUND OF THE INVENTION

The following invention relates to a method
5 and apparatus for connecting two semiconductor devices
together or for connecting a semiconductor device to a
passive circuit by means of a coplanar waveguide that
is free from inductive reactance at high frequencies.

Small integrated circuit elements such as
10 microprocessors are typically connected to other larger
semiconductor devices such as hybrid integrated cir-
cuits by wire bonding. The wire bonding technique
utilizes a special machine to fuse extremely small
diameter wires to the contact points or bond pads of
15 these smaller IC chips. This method of physical inter-
connection of one semiconductor device to another is
adequate where the upper limit of the frequency of the
signal between the devices is less than 10 megahertz.
At frequencies of around 100 megahertz, however, the
20 bond wire begins to behave as an inductor inducing a
reactive component in the connection that attenuates
the signal level. This attenuation takes the form of
a subtraction effect that occurs when a certain portion
of the input frequency wave is reflected back to the
25 source from the wire bond connection. At frequencies
in the gigahertz range, the wire bond becomes an almost
pure inductance which severely retards the incoming
signal, and at a range of 10 to 30 gigahertz there may
be complete attenuation.
30 In hybrid IC chips, that is relatively large
chips which include a ceramic substrate, high-frequency
RF signals, are transmitted via a transmission line
imprinted on the chip. Such transmission lines are
described generally in a text, Gupta, Garg, and Bahl
35 "Microstrip Lines and Slotlines" (Artech House, Inc.,
1979). The transmission line on such circuits may take
the form of a coplanar wave guide which includes a

signal-carrying conductor flanked on opposite sides by
a pair of ground plane conductors. All of the conduc-
tors extend substantially parallel to one another and
are coplanar. It is at the interface between the
5   transmission line of the hybrid IC chip and a smaller
integrated circuit usually referred to as a die that
the bond wire connection described above is made. The
transmission line of the hybrid IC is fully capable of
handling frequencies in the gigahertz range but the
10   inductive problem described above is encountered when
attempting to connect the IC die to the hybrid IC
transmission line.

SUMMARY OF THE INVENTION

15   The inductive problem posed by wire bond
connections is solved in the present invention by
providing a continuation of the transmission line of
the hybrid IC in a configuration that essentially pre-
serves the predetermined impedance of the transmission
20   line. Thus the impedance remains constant from medium
to medium and does not result in any attenuation of the
signal due to inductive loading at the connection be-
tween the hybrid IC and the smaller IC die.
           According to the invention, three thin
25   metallic straps supported by a dielectric substrate are
pressure-bonded to respective electrical contact points
on the hybrid IC and the IC die. The three straps,
which lie in the same horizontal plane, form a contin-
uation of the transmission line of the hybrid IC. The
30   center strap is a signal-carrying conductor and the
straps on either side of the center strap form a ground
plane. The straps are formed on a polyimide substrate
which is a planar sheet of dielectric material. The
straps are, in addition, embedded in the polyimide
35   sheet so that the gap width between each of the straps
is substantially filled with dielectric material.

The individual widths of the connecting straps are such that the outer straps may function as a ground plane. Typically the signal-carrying strap has a width of approximately 2.5 mils and the outer straps

5 have a width of 6 mils. With these widths it is possible to calculate the overall impedance of the microstrap waveguide. This impedance is equal to the square root of the ratio of inductance to capacitance. Once the impedance is known, it is possible to adjust the

10 capacitance of the microstrap waveguide by adjusting the gap spacing between the signal-carrying central line and the two adjacent flanking ground plane lines. Since the gap is substantially filled with a dielectric material, these lines provide a capacitive reactance to

15 an incoming signal which may be adjusted by dimensioning the gap within tolerances achievable by existing machinery used for such purposes.

The actual physical connection between the two semiconductor devices is made by first cutting the

20 polyimide substrate containing the microstrap connection to the required length and width and pressure bonding the ends of the microstraps to the respective electrical terminals on the hybrid IC and the IC die.

It is a primary object of this invention to

25 provide an electrical connection between two semiconducting devices capable of handling extremely high-frequency signals with little or no signal attenuation.

A further object of this invention is to provide a coplanar wave guide-connecting link between

30 two semiconducting devices which may be bonded to each semiconducting device using conventional pressure-bonding techniques.

Yet a further object of this invention is to provide a connecting link between two semiconducting

35 devices which overcomes the problem of inductive reactance caused by previous wire bonding techniques.

Yet a further object of this invention is
to provide a coplanar wave guide transmission link
between a hybrid IC chip and an IC die in which the
transmission link has an impedance matching that of the
5   impedance of the hybrid IC.

The foregoing and other objectives, features,
and advantages of the invention will be more readily
understood upon consideration of the following detailed
description of the invention, taken in conjunction with
10   the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a coplanar
wave guide microstrap connecting a hybrid to an IC die.
15   FIG. 2 is a top view of the connection of
FIG. 1.

FIG. 3 is a cutaway view taken along line 3-3
of FIG. 2.

20   DETAILED DESCRIPTION OF THE INVENTION

An integrated circuit chip 10, hereinafter
referred to as a "die" is physically mounted and
affixed to a hybrid integrated circuit 12. The hybrid
circuit 12 has imprinted on its surface a coplanar
25   waveguide 14 comprising a signal-carrying strip 16 and
adjacent ground plane strips 18 and 20. A coplanar
microstrap waveguide 22 forms the electrical connection
between the ends of coplanar waveguide 14 and electri-
cal terminal points 24 on the die 10.
30   The structure of the coplanar microstrap
waveguide 22 is shown in more detail in FIGS. 2 and 3.
A substrate 26 formed of a thin dielectric material
such as polyimide forms a support base for three co-
planar straps 28, 30 and 32 oriented substantially
35   parallel to one another on the substrate 26. Ground
plane straps 28 and 30 are disposed one on either side

of a central signal-carrying strap 32. The signal-
carrying strap has mitered ends 34 and 36 whose func-
tion will be explained below.

As shown in FIG. 3, the signal-carrying strap
5   32 and each of the ground plane straps 28 and 30,
respectively, are substantially embedded in polyimide
substrate 26. Embedding the straps in this manner
causes the spacings 38 and 40 between adjacent pairs of
straps 30 and 32, and 32 and 28, respectively, to be
10 substantially occupied by the dielectric material of
substrate 26.

Each of the ground plane straps 30 and 28 has
a predetermined width designated as d1 in FIG. 2. The
signal-carrying strap likewise has a predetermined
15 width exclusive of the mitered ends and is designated
as d2 in FIG. 2. The dimension d1 of the ground plane
straps 30 and 28 need only be wider than a minimum
value in order for the straps to function as true
ground planes. Thus d1 could be made wider if desired.
20 In the preferred embodiment, the dimension d2 is 2.5
mils and the dimension d1 is 6 mils. Thus, d1 could be
wider than 6 mils but this would confer no appreciable
benefit on the configuration since a 6-mil width is
sufficient to cause straps 30 and 28 to function as a
25 ground plane for 2.5-mil-wide signal-carrying strap 32.
The spacings between adjacent straps 38 and 40 are .5
mil each in the preferred embodiment. The presence of
a dielectric material in spacings 38 and 40 permits the
spacing to be wider than that which would otherwise be
30 permitted. For example, if air were used as a dielec-
tric, the adjacent spacings between the straps would
have to be on the order of .17 mil which is a difficult
tolerance to maintain with conventional manufacturing
processes.

35   The coplanar waveguide microstrap is a
continuation of the coplanar waveguide 14 imprinted on
hybrid circuit 12. As such, it is intended to have the

same impedance as coplanar waveguide 14 which is
usually on the order of 50 ohms.

The impedance of any coplanar waveguide is
determined by the formula $Z_0 = \sqrt{L/C}$ where Z_0 is the
5 impedance of the waveguide, L is the inductance and C
is the capacitance. The impedance of a coplanar wave-
guide structure thus depends upon the capacitance
between the conductors 28, 30 and 32 which, in turn,
depends upon the dielectric constant of the substrate
10 material, the dimensions of the microstraps, and the
spacing or gap between the center signal-carrying
conductor and the two ground plane conductors.

In the preferred embodiment it is desirable
to make the center or signal carrying strap 32 as small
15 as possible so that it may be physically bonded to the
connection terminals 24 of the IC die 10. These termi-
nals are designed primarily for wire bonding and there-
fore the dimensions of the strap should, if possible,
at least attempt to approach the dimensions of the wire
20 with which the connection terminal was intended to be
used. A practical limit which is inherent in the manu-
facturing process for microstraps of the type discussed
herein is on the order of 2.5 mils.

As shown in FIG. 3 the microstraps 28, 30 and
25 32 are substantially embedded in the dielectric sub-
strate 26. A thin top surface may protrude above the
substrate 26 but it is preferred that the microstraps
28, 30 and 32 be flush with the top of substrate 26.
Thus, the gaps 38 and 40 are substantially filled with
30 dielectric material. The thickness of each of the
micro straps 28, 30 and 32 should be as small as possi-
ble but again the practical limits of conductor thick-
ness dictate that the lower limit for such thickness is
approximately 8 microns ±2 microns.
35 Knowing the dimensions of the microstraps
and assuming that the dielectric material of the
polyimide substrate substantially fills the adjacent

spacing between microstraps, the impedance of the coplanar waveguide thus formed may be determined by reference to the text entitled "Microstrip Lines and Slotlines" Gupta, Garg and Bahl (Artech House, Inc.,
5   1979), pages 257-267, which is incorporated herein by reference. Using the Gupta text, for any desired impedance, the gap spacing between adjacent microstraps may be determined and accordingly adjusted. As mentioned previously, the normal impedance of a coplanar
10 waveguide impressed upon a hybrid IC is usually 50 ohms. This dictates the result that in the preferred embodiment with its given parameters the gap spacings 38 and 40 should be .5 mil each.

As shown in FIG. 2 the conductors overlap the
15 substrate enough to allow physical bonding of the ends to the hybrid IC 12 and the IC die 10. In order to reduce stray capacitance at each end, signal-carrying strap 32 includes mitered ends 34 and 36. This keeps the impedance of the coplanar waveguide 22 substan-
20 tially constant over its entire length.

In order to form the coplanar waveguide microstrap 22, predimensioned thin straps of a predetermined length, made preferably of gold or a noble metal, are imbedded in a sheet of polyimide having a
25 predetermined length. The straps overlap the ends of the sheet which is then trimmed to remove excess material. The ends of the microstraps 28, 30 and 32 are then pressure bonded to respective electrical terminal points on the IC die 10 and on the Hybrid IC 12.
30 A conventional pressure bonding machine may be used for this step, an example of which is a Kulicke Soffa Model No. 4010 Wedge Bonder from the Kulicke Soffa Co. of Horsham, Pennsylvania.

Although gold is preferred for making the
35 microstraps, other metals having high conductivity such as silver, copper or aluminum may also be used.

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The terms and expressions which have been
employed in the foregoing specification are used
therein as terms of description and not of limitation,
and there is no intention of the use of such terms and
5 expressions of excluding equivalents of the features
shown and described or portions thereof, it being
recognized that the scope of the invention is defined
and limited only by the claims which follow.

1. An electrical connection between a pair of electrical devices comprising a plurality of substantially parallel coplanar metallic straps supported by a dielectric substrate including at least one signal-carrying strap and adjacent ground plane straps disposed one on either side of the signal-carrying strap so as to form spacings of a predetermined width between the signal-carrying strap and each of the ground plane straps.

2. The connection of claim 1 wherein the signal-carrying strap has mitered ends.

3. The connection of claim 1 wherein the straps are embedded in the dielectric substrate such that the adjacent spacing between any two straps is substantially occupied by the dielectric substrate.

4. The connection of claim 1 wherein the straps are formed of gold.

5. The connection of claim 3 wherein the predetermined spacing between adjacent straps is chosen to provide a predetermined impedance for said electrical connection which matches the impedance of at least one of the electrical devices.

6. A method of connecting two electrical devices together comprising the steps of:

    (a) forming on a dielectric substrate three
         substantially parallel metallic con-
         ducting straps of respective predeter-
         mined widths, said straps having
         predetermined spacings therebetween so
         as to form a coplanar waveguide having a
         center signal-carrying strap and two
         adjacent ground plane straps;

(b) cutting said substrate and metallic straps to a predetermined length and width; and

(c) pressure-bonding the ends of said metallic straps to respective electrical terminal points on each of said electrical devices, respectively, to form an electrical connection between the two devices.

7. The method of claim 6, further including the step of embedding the metallic straps in the substrate so that the dielectric material substantially fills the spacings between adjacent straps.

8. The method of claim 6 wherein each of said metallic straps are formed of gold.

9. The method of claim 6, further including the step of determining the impedance of the coplanar waveguide as a function of the spacings between adjacent straps and adjusting said spacings to provide an impedance for the waveguide that substantially matches the impedance of at least one of the electrical devices.

10. The method of claim 6, further including the step of mitering the ends of the center signal-carrying strap.
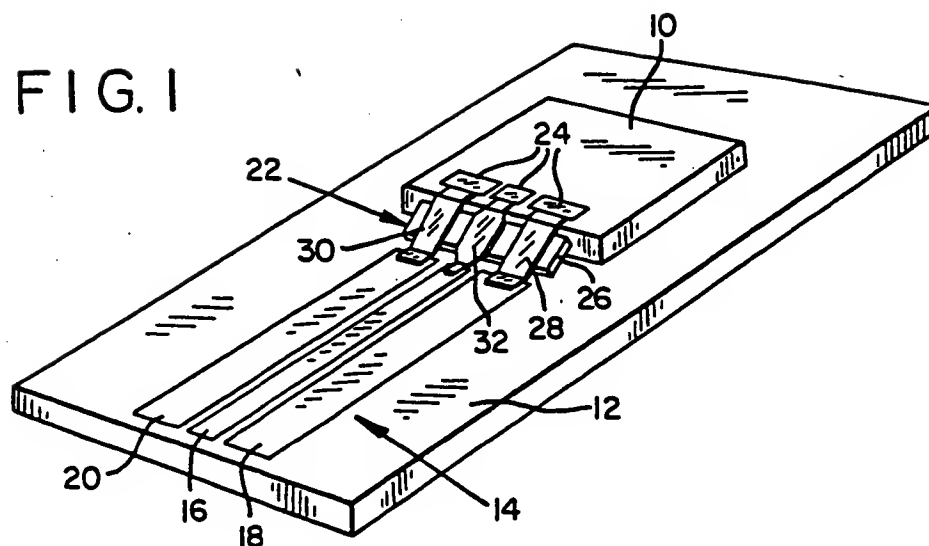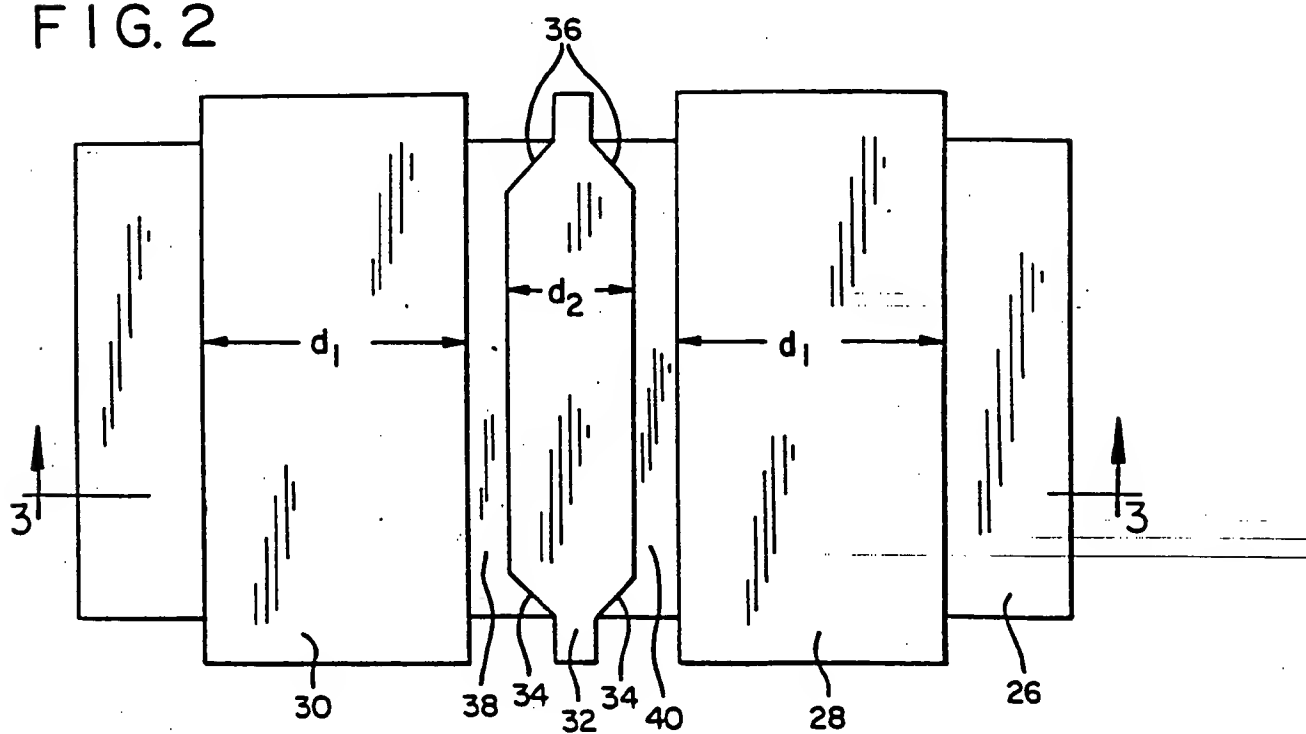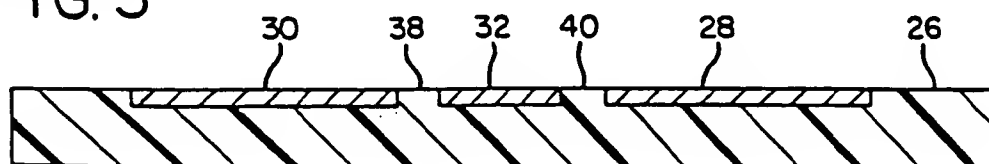
FIG. 1

10

24

22

30

26

32

28

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16

18

12

14

FIG. 2

36

d_2

d_1

d_1

3

3

30

38

34

32

34

40

28

26

FIG. 3

30

38

32

40

28

26

European Patent
Office

EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-3 786 375 (H. SATO et al.) * column 3, lines 17-37 *	1,5	H 01 L 23/48 H 01 L 23/56
A	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-29, no. 12, December 1981, pages 1266-1271, New York, US; C.T. RUCKER et al. "Chip level IMPATT combining at 40 GHz'" * figure 3 *	1,6	
A	PATENT ABSTRACTS, vol. 8, no. 29 (E-226)[1466], 7. February 1984; & JP - A - 58 191 453 (NIPPON DENKI) 08-11-1983	2	

TECHNICAL FIELDS
SEARCHED (Int. Cl.4)

H 01 L   23/48
H 01 L   23/56
H 01 P   3/08
H 01 P   5/08

The present search report has been drawn up for all claims

Place of search BERLIN	Date of completion of the search 29-05-1986	Examiner GIBBS C.S.

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